

THE
DAILY USES
OF
NAUTICAL SCIENCES,
IN
A SHIP. AT SEA;
PARTICULARLY,
IN
FINDING and KEEPING
THE
LATITUDE
AND
LONGITUDE,
DURING A VOYAGE.

BY SAMUEL DUNN, *K*

Teacher of the Mathematical Sciences,

LONDON.

Printed for the AUTHOR,
at N^o. 1. Boar's-head Court, Fleet Street.

MDCCXC.

DAILY USES
OF
NAUTICAL SCIENCES.

SECTION I.

THE NAUTICAL SCIENCES used in a Voyage, are, first *Arithmetic* the Science of Numbers; secondly, *Geometry* the Science of Magnitudes; thirdly, *Astronomy* the Science of the Celestial Bodies. By *Arithmetic* all scientific calculations are made. By *Geometry* the extent, positions and situations of places are expressed in *Geography*, *Hydrography* and *Navigation*. By *Astronomy* the Tides or ebbing and flowing of the Seas are predicted, and the place of a Ship at Sea is found, by calculating observations made with proper instruments.

II.

In writing the Theory and Practice of Navigation, Order requires the most easy and simple Principles first, next to these are to come things that are more complicated, and last of all, or toward the conclusion of the subject, such propositions and problems, as are derived from cases before treated of; but,

In the daily and hourly practice of *Navigation* at Sea, such observations and calculations are to be made as are wanted to be applied, at all times during a Voyage; for by these the Ship's place is determined and known.

On this account the most difficult parts of Nautical Science may sometimes be wanted at the Beginning of a Voyage, at other times near the Middle, or toward the End; sometimes in sailing from or approaching toward a Coast, at other times in the open Seas, as the case may happen.

Navigation

Navigation is greatly promoted by the knowledge of three things, the Situations of Places sailed from and to, and of all Places during a Voyage.

III.

When a Ship is at an inland Port or place remote from the Sea, there should be known

1. The Latitude of the Place.
2. The Longitude of the Place.
3. The Variation of the Compass.
4. The adjacent Dangers.
5. The Time by the Ship's Clock.

If any of these are not known, they should be taken or discovered, in order for ready use.

Here follow Methods for Latitude in Harbours.

IV.

First Method for Latitude in Harbours.

By a good Chart of an Harbour and the adjacent Places; not only the Latitudes but the Longitudes, Variations, Places of Danger, and others, will appear by Inspection.

Second Method for Latitude in Harbours.

When no Chart of the Ship's place is had, the Latitude should be taken by help of an artificial Horizon.

First kind of artificial Horizon.

Pour a little Water, Oil, Treacle, or any other Fluid, into a Plate, Saucer, or any other shallow Vessel.

Second kind of artificial Horizon.

Pour a little Quicksilver into any such Vessel, and lay thereon a small piece of Glass truly ground and having parallel Planes.

To take an Altitude by either of these.

Adjust Hadley's Octant or Sextant as directed in Longitude at Sea, Section 138. or Nautic Propositions Sect. 15.

With this Instrument, bring down the Sun or other Object by double Reflection, to cover the Image thrown up by single Reflection from the Fluid, and half the Index-distance from 0 on the Arch, is the observed Altitude, to be corrected only for the Refraction in Altitude.

Take the meridian Altitude of either Sun, Moon, Planet or Star, by this Method, then proceed for the Latitude as directed in

Longitude at Sea, Sect. 53.

Nautic Propositions, Sect. 19. 20.

Practical Navigation, Art. 69. 74.

Third Method for Latitude in Harbours.

When no meridian Altitude can be taken, but one Altitude can be taken very near Noon and another Altitude at any other time on the same Day, two such Altitudes being taken and the time elapsed between them being measured by the ship's Clock or a Watch, the Latitude may be had as directed in

Longitude at Sea, Sect. 122.

Formula for the same.

Fourth Method for Latitude in Harbours.

When two Altitudes are taken between Nine in the morning and Three afternoon, the Latitude may be found as directed in

Longitude at Sea, Sect. 119.

Logarithms, Sect. 29.

Formula for the same.

Fifth Method for Latitude in Harbours.

When two Altitudes are taken at any two times of the Day and the celestial Bodies do not ascend
nor

nor descend nearly in a perpendicular to the Horizon, the Latitude may be taken as directed in Longitude at Sea, Sect. 121.

Nautic Propositions, Sect. 28.

Formula for the same.

This method of Approximation is often fast in high Latitudes. In the Torrid Zone, this Method may be used by observing two Stars having different Right Ascensions and Declinations; then, their Altitudes taken at the same time, and the difference of their Right Ascensions (or rather their equatorial distance) used as the elapsed-time, gives the Latitude.

Sixth Method for Latitude in Harbours.

When of two Stars, one of them happens to be near the Meridian, and the other otherwise situated, the Latitude may be found by taking their Altitudes at the same time, as directed in

Longitude at Sea, Sect. 124.

Formula for the same.

Seventh Method for Latitude in Harbours.

When any two Altitudes of the Sun and the Elapsed-time are taken, the Latitude may be found as directed in

Longitude at Sea, Sect. 115.

Practical Navigation, Art. 86.

Other Methods for Latitude in Harbours.

When the Sea can be seen, the Horizon of the Sea may, at proper times, be applied. In such cases, by the Octant or Sextant, the Object is brought down to the Horizon of the Sea, in the forward or backward observation, and the Altitude is taken.

Hence it follows that, when a Ship is nearly entering into an Harbour, or nearly out of it, where the Horizon of the Sea can be seen; no opportunity

opportunity should be omitted, to get the Latitude by any of the Methods beforementioned.

Here follow Methods for Longitude in Harbours.

V.

First Method for Longitude in Harbours.

The First Method is that by Sights of Sun and Moon in the Day-time. The Distance, Sun's Altitude and Moon's Altitude are taken at or near the same time, and by them the Longitude is found as directed in

Longitude at Sea, Sect. 146.

Peculiar Tables, Sect. 26.

Formula for the same.

Second Method for Longitude in Harbours.

The second Method is by Sights of the Moon and a zodiacal Star in the Night-time, as directed in Longitude at Sea, Sect. 147.

Peculiar Tables, Sect. 26.

Formula for the same.

In either of these Methods, the true Distance of Centres may be found by finding the two Arcs, or by finding the Angles at Sun and Moon or Moon and Star, and the Corrections from them.

If the latter be used, those Angles can be found with but four Figures of Logarithms, beside Index, more exact than any instrumental Construction will shew them by Inspection, whilst five or six figures may be used; and the little trouble this affords, rewards a Calculator amply with Truth and Certainty,

Third Method for Longitude in Harbours.

In this Method, a Watch or Time-keeper is set to mean Solar-time by help of an Equation Table and an Observation, in a known Longitude, as the time at the Ship is found in the two former Methods.

The

The Time-keeper is then let to go on, and supposing it to gain, lose, or keep exactly to mean Solar time, an observation is made for the Time at the Harbour; then, the difference between its Solar-time, and the Time-keeper's Solar-time, is the Longitude, as directed in

Longitude at Sea, Sect. 68.

Peculiar Tables, Sect. 4.

Other Methods for Longitude in Harbours.

In settling the Longitudes of Harbours, they may have been known near the truth by the run of Ships from other places whose Longitudes have been well determined, or from Journeys, or from Lunar Eclipses, or from the Immersions and Emerisions of Jupiter's Satellites, or by several other Methods, as directed in

Longitude at Sea, Sect. 67. 64. 62.

VI.

To take the Variation in Harbours.

The Variation of the Compass in an Harbour, is necessary for knowing nearly the times of the Tides. It is found by experience that in Harbours and Rivers near the Seas of great extent, and small Inlets connected with them, the Tides happen always nearly the same number of Hours and Minutes after the Moon is past the Meridian; and therefore, reckoning eight Points of the Compass-card to be six Hours of time or ninety Degrees, it is customary to allow one Point of the Compass-card to three Quarters of an Hour of Time or eleven Degrees and a quarter of the Horizon.

In this Proposition, the Moon's true Bearing at the time of High Water is a spherical Angle formed at the Pole of the Equator, but the supposed Bearing by the Compass, is a spherical Angle formed

at

at the Zenith, and what these differ is the Error, supposing no Variation.

The operation for finding the Variation, is in
Longitude at Sea, Sect. 56. 57.
Nautic Propositions, Sect. 24. 25.
Practical Navigation, Art. 75. to 83.

The Variation in most Harbours, differs but little from that at the adjacent Coasts, and therefore it should be carefully taken, and its Alteration from time to time observed.

VII.

The Dangers in Harbours and in the adjacent Places, are best known when they have been carefully discovered and laid down accurately in a Plan or Chart. These will then appear by Inspection on the Chart, in their proportionate Positions and Distances as they are on the Land and Waters.

VIII.

To set the Ship's Clock or a Watch to the Time of Day or Night.

When a Clock or Watch is to be set to Time, an Altitude is to be taken of the Sun by Hadley's Octant or Sextant, and at the same time, the Hour, Minute and Second shewn by the Clock or Watch, is to be written down; then a calculation is to be made to find what distance the Sun was from the Meridian, either past or short of it, when the Altitude was taken, and if they agree the Clock or Watch is at Solar-time, otherwise the error appears.

In like manner a Star may be used, and by help of the Sun and Star's Right Ascensions the Solar-time at the Ship may be found as directed in

Longitude at Sea, Sect. 113.

Solar-time is that which comes directly from observations of the Sun's Altitude, and it is that by which

which astronomical Appearances are reckoned; but mean Solar-time is that which Clocks and Watches would keep, could they be made to go equally fast from the beginning to the end of the Solar Year. The Calculations for Solar-time, are in

Longitude at Sea,	Sect. 54.	III.
Logarithms,	Sect.	26.
Nautic Propositions,	Sect.	28.
Peculiar Tables,	Sect.	31.
Practical Navigation,	Sect. 84.	85.

If a Clock or Watch be kept nearly to Solar-time, and either newly set by an Observation or examined at the end of every few Days, it will more readily shew the times when the Celestial Bodies pass the Meridian, than if it be kept to mean Solar-time; but this is to be noted, to avoid Error. This Clock or Watch, is only for reminding the Observer to make Observations at proper times of the Day or Night. The Time-keeper is for the Longitude.

IX.

Of the Times when the Tides happen.

The common Method of observing the Tides is by the Moon's Bearing; but this, as already noted, is very erroneous, especially in the Torrid Zone; the more correct way is by the Hours and Minutes when the Moon is past the Meridian both North and South. The Rules are in

Nautic Propositions,	Sect. 4.
Practical Navigation,	Art. 17. 26.

X.

Of a Voyage provided for, and begun.

First. It should be known, what a Time-keeper to be used gains or loses daily, when compared with mean Solar-time, whilst the Ship is in Harbour.

2. The Ship's Time and a Table, should shew the times of the Tides, at all adjacent Places. These should be observed.

B

3. By

3. By the Longitude, the Ship will begin the Voyage, from a place that will agree with the difference of Longitude made, and that observed after the beginning of the Voyage.

4. By the Variation, the Voyage will be begun with a Course that will not give a very erroneous difference of Latitude and Departure.

5. The Increase or Decrease of the Variation will be known near the Coast and toward the Ocean. This alone may be a good caution to Ships in their approach toward the Land. Hereby,

6. The course to come into an Harbour may be known, when a Ship is off Land, and thereby the Dangers may be avoided.

7. By the Ship's Time, the Longitudes of Places near the Coast may be known, as the Ship passeth near them; and a Time-keeper may be set more accurately to mean Solar-time, for any other Meridian whose difference of Longitude is known, near the beginning of the Voyage.

8. Under these Precautions, when the Ship departs from Land and begins the Voyage, the Latitude will be known with but little error, and the Longitude with no more error than has arisen from settling the Longitudes of Places that have been applied.

XI.

The Ship being now at Sea and on the Voyage, all the *Nautical Sciences* are at hand, to determine the Latitude and Longitude at every Hour of Day and Night, during the Voyage.

First Method for Ship's Place at Sea.

This Method is that of Practical Navigation, by the Course and Distance sailed, as directed in

Longitude at Sea,	Sect. 67.
Practical Navigation,	at large.
Nautic Propositions,	at large.
Longitude Journal,	at large.

A necessary

A necessary Precaution for practising the Second Method for Ship's Place at Sea.

First. Set the Ship's Clock or a Watch to the Ship's Time, and every Day at Noon, move its Minute-hand as much forward as the Difference of Longitude is made in the former Day Eastward; but as much backward as the Difference of Longitude made in that time Westward.

Secondly. Set another Clock or Watch to the Ephemeris Time as nearly as possible, and as often as opportunities for taking the Longitude permit, keep either this Clock or Watch to Ephemeris Time.

Two Spring Clocks or Pocket Watches, being thus set, they may be advantageously applied in taking the Latitude and Longitude by Observations, as follows.

First Method for Latitude at Sea by Observations.

By knowing the Time near Noon, take the Sun's Meridian Altitude, and thereby the Latitude.

Second Method for Latitude at Sea by Observations.

Take the equatorial Distance of either a Fixed Star or Primary Planet from the Sun, and by help of the adjusted Clock or Watch take its Altitude when nearly on the Meridian. Measure the Elapsed time and take another Altitude of the same. Then, by the third Method for Latitude in Harbours, the Latitude will be found.

Third Method for Latitude at Sea.

When the Ship's Latitude is great either North or South; take two Altitudes of the Sun, and the Elapsed-time, and then compute the Latitude, as in the fifth Method for Latitude in Harbours.

Fourth Method for Latitude at Sea.

When two Altitudes of the Sun are taken within three Hours of Noon; by them and the Elapsed-time,

time, compute the Latitude as in the fourth Method for Latitude in Harbours.

Fifth Method for Latitude at Sea.

When the Altitudes of two Stars are taken, and one of them is near the Meridian; the Latitude may be found, as in the sixth Method for Latitude in Harbours.

Sixth Method for Latitude at Sea.

When the Altitudes of any two Stars have been taken, and the Ship is in high Latitude; the Latitude may be found by computing as in the fifth Method for Latitude in Harbours.

Seventh Method for Latitude at Sea.

When two Altitudes of a Fixed Star or Planet are taken, within three Hours of passing the Meridian each; the Elapsed-time reduced to Solar-time, and a computation as in the fourth Method for Latitude in Harbours, gives the Latitude.

Eighth Method for Latitude at Sea.

When the Meridian Altitude of the Moon's lower or upper limb has been taken, and the Declination is known by having the Ship's rough Longitude, or otherwise by the rough Time at the Ephemeris's Place; the Meridian Altitude cleared from Semi-diameter, Dip and Refraction, gives the Latitude, as in the first Method.

Other Methods arising from the Analysis of the Sphere, and the Change of Declination, are in the Principles from which these Methods have been deduced. Consequently, the Sun and Moon in the Day time, and the Moon and Stars in the Night, may be applied for the Latitude at Sea, in the same manner as before directed, first clearing the Moon from Parallax in Altitude, and reducing her hourly change of Right Ascension to the Equator.

The

The Lunar Method for Longitude, becomes less correct with small Altitudes, and the Ship's true Latitude should be known, near times when the Lunar Method is practised for Longitude, at Sea.

First Method for Longitude at Sea.

This Method is the same as the first Method for Longitude in Harbours; only, here the Horizon of the Sea is used in taking the Altitudes.

Second Method for Longitude at Sea.

This is the same as the second for Harbours; using the Horizon of the Sea, for the Altitudes.

Third Method for Longitude at Sea.

This is the same as for Harbours; having first set a Clock or Watch to the Ship's Time, and allowed for the difference of Longitude made, from the Time the Clock or Watch was set, to the Time of Observation.

When the Altitudes cannot be taken they may be inferred, as directed in

Longitude at Sea, Sect. 141.

Fourth Method for Longitude at Sea.

In this Method, a Timekeeper is set to mean Solar-time, by an artificial or the natural Horizon of the Sea, at the beginning of the Voyage; as in Sect. 5. Method 3. for Longitude in Harbours.

By the same Method, at Sea, the mean Solar-time is found, and compared with that shewn by the Time-keeper; and the Sum or Difference, as the Case requires, is the Longitude.

Other Methods for Longitude at Sea, are in Longitude at Sea, Sect. 58. 59. 60. 61. 62. 63. 64. 65. 66. In peculiar Charts and Tables, and Atlas of Magnetic Variations.

In any Method for Longitude at Sea, two things are necessary; proper Accuracy, and Ease in making the Observations and Calculations.

XII.

When a Ship is at Sea, all the foregoing Methods of taking the Latitude and Longitude, may be practised at such times as the Weather will permit.

First. The Method by Course and Distance sailed, under all its Improvements, is to be practised hourly; as directed in the Instructions prefixed to the *Longitude Journal*.

2. Whenever the Latitude is doubtful and wanted to be known; from Sun-rising till near Noon, and from till near Noon to Sun-setting, with the Elapsed-time, are very favourable opportunities for taking the Latitude; and likewise the Longitude, when the Moon is not too near to or too remote from the Sun.

3. Between Nine in the morning and Three afternoon the Latitude may always be taken, and frequently the Longitude.

4. The Method by Error in the computed Hour-angles, or Errors in the Differences of Stars Right Ascensions, will determine the Latitude; and frequently the Longitude may be taken, when the Moon's angular Distance is taken at one of the Times.

5. When, in the Day-time, the Sun or the Moon is near the Meridian; or, in the Night, the Moon or zodiacal Star is near the Meridian, the Latitude and Longitude may be taken, without Elapsed-time.

6. Universally, from Sun-rising to Sun-setting, when the Sun and Moon appear; or in the Night when the Moon and Stars appear, the Latitude and Longitude may be taken, by working the several triangles which are in the Problem; but this is the last Method to be had recourse to, although it may be greatly assisted by taking out the Logarithms to a few seconds in the Author's Treatise.

7. Whilst all these Methods do command a proper Answer for the Ship's Place, and others that

that might be introduced, the Method for Latitude by Meridian Altitudes should never be omitted, when they can be practised with certainty.

XIII.

The Utility of the Longitude Journal.

When the Latitude and Longitude have been taken by any of the foregoing Methods; and by repeated Observations, they differ from the Ship's Place deduced by Course and Distance sailed, and no errors in the Observations can have occasioned such Difference, it is time to suspect that it must have arisen from Currents or other causes. Such deceptions may in some cases arise from causes that are almost constant, but in the wide Oceans, without doubt they are different, and therefore are not always the same, nor ever return. At such times the Longitude Journal registers every evidence in the most natural and regular manner. These Methods for deducing the Ship's Place, are several of them adapted for near Noon, which is the best time for settling the daily Account.

XIV.

Of Tables used in Days Works.

The Tables used in making up a Day's Work, or finding the Latitude and Longitude of the Ship by the Courses and Distances sailed, are,

1. *The Tables of Degrees and Minutes*, answering the *Points* and parts of a *Point* on the *Compass-card*. This is used in reducing the observed Course to the true Course, having the Variation.

2. *The Table of Difference of Latitude and Departure*. Having the Course in Degrees and Distance sailed, this decimal Table, sheweth the difference of Latitude and Departure to tenths or hundredths of a Mile, when the Distance is in Miles and not more than one hundred. For greater Distances, to one thousand

or

or ten thousand Miles, it takes a Figure more, in the Distance, in the Difference of Latitude and in the Departure; and when necessary, they add together.

By this Method, the Difference of Latitude and Departure, are found to a Tenth of a Mile, from a Mile to ten thousand Miles of Distance, and for any Course, to the nearest half Degree of the Quadrant. Thus, all the Differences of Latitude and Departure in a Day's Work are found, and their total found. Then, the Logarithm of the Departure, added to the half Sum of the Secants less Radius of the Latitudes sailed to and from, gives the Logarithm of the Difference of Longitude made in the Day's Work.

This Method is nearer the truth than Middle-latitude sailing, and it is both shorter and truer than Mercator in large Courses; because such in Mercator's sailing, require six places of Figures in meridional Parts, instead of four, for the same accuracy by this Method.

3. The *Navigation Table*, shewing by inspection the Course and Distance made good, having the Difference of Latitude and Departure. This shews the particulars by doubling, trebling, &c. the Difference of Latitude, the Departure, and the Distance made good, but not altering the Angle of the Course. Farther, by entering this Table, with the Departure under Latitude, and the Latitude or Middle-latitude of the Ship under Courses; is shewn the Difference of Longitude by inspection. The like by the former Table, but not so readily.

By this Table, all the cases, relative to the Bearings and Distances of Land seen in a Voyage, are solved by inspection; and it may be applied with ease and certainty, in sailing a whole Day by the Magnetic Courses, deducing the true Difference of Longitude therefrom, and comparing it with that by the Method before directed.

Thus

Thus will all that is immediately necessary in Days Works, be more easily and expeditiously done, than by the best Methods that have been hitherto practised or published; and there will be the more leisure near Noon, for making such Observations as will more certainly determine the Ship's place in Latitude and Longitude, by applying the astronomical Rules and Formulas, which are peculiarly designed for that purpose. The other Cases in Practical Navigation are but few if any, and they may be solved, when they are wanted, with greater ease than by Mercator, by the Logarithms.

XV.

Uses of the Longitude Journal.

When the Ship's Latitude and Longitude have been determined by the usual method of Sailing, as before directed, entered in the *Longitude Journal*, and the Ship has been so long at Sea, that it may be necessary to examine the truth of such entries; any of the Methods beforementioned are to be applied, as the weather permits, either by Day or Night, to find the error if there be any.

1. In the Day-time, the Latitude may be taken, by Meridian Altitudes of either Sun or Moon (when the latter is visible) or otherwise, by Altitudes of the Sun and Elapsed-time. 2. In the Night, the Latitude may be taken by Meridian Altitudes of the Moon, or other Planets or Stars; also, by the Stars without Elapsed-time, by any of the forementioned Methods. This Latitude is to be written in the Journal, opposite to the Hour when taken, and the nearer it is either to Noon, or to the time when an Observation is made for the Longitude, the easier it will be to infer the true Latitude to be used with the Distance and two Altitudes, for determining the Longitude of the Ship.

C

As

As the Latitude is taken and inserted opposite to its Hour, so is the Longitude to be taken, by any of the foregoing methods, by Day or Night, and placed opposite to the Hour when it is taken; in the most concise manner, retaining particulars of the observation, in a single line at the bottom of the Journal.

Hence, the Difference between the Ship's place by Reckoning and that by Observation will often be known soon after Noon, and at other times of the Day, when these have been compared; and when there is reason to suspect error in the results of the Observations, or when repeated the Observations agree, but differ from the Reckoning, it will be proper to use the Observations as cautions against error and danger.

The errors by Courses and Distances are so great in long Voyages, through various causes, that the observed Longitudes may at once be put in the Journal instead of those by the Reckoning; by this, a great deal of unnecessary calculation of Days works may be saved in the remaining part of the voyage. Or, the ship's Reckoning may be continued, and then it will appear by inspection how much the ship's Reckoning has differed from the observed place, at all times during the Voyage.

Thus Blank-Charts and Delineations on them for shewing errors in the Ship's place, as derived from the Reckoning, will not be wanted for the Oceans, for the Journal itself will shew it, by inserting both the results of the Reckoning and Observations for every Day at Noon.

When the Ship comes near Land, and it is has a good Time-keeper, it may be used with the Courses and Distances failed to great advantage, for avoiding dangers, finding the Positions, Soundings and other particulars near an unknown Coast. At such times the Lunar Method is only applicable for determining the Latitude and Longitude of some particular

ticular place on the Coast, the Time-keeper is applicable only in greater Distances than can be taken by measuring the Lines, Angles and Curvature of the Coast on the Spot; all this is to be done by the Methods of Triangles and Practical Navigation, and therefore belongs to Coast Surveying, which is not pursuing a Voyage to a known Port.

XVI.

Other Transactions to be placed in the Journal opposite to the Hours when the Observations were made, are as follows.

1. The Variation of the Compass taken by Amplitudes.
2. The Variation by Azimuths.
3. The Bearings and Distances of Lands appearing, disappearing, or as seen, with Sketches of those appearances in profile at the bottom of the Journal.
4. The Soundings, with their diminutions in approaching toward the Coast.
5. The Time of the Tides in Solar-time by the Ship's Clock or Watch; or otherwise, the Bearing of the Moon at the time of the Tides, with the Variation of the Compass.
6. The Tides off the Land, and near the Coast, if possible.
7. The Variation approaching the Coast.

To these may be added such other articles of a scientific kind as require hourly Notice, and when there is room, for want of these or the foregoing, there may be entered in their stead, the state of the ship's Rigging or such other alterations as take place at a particular Hour, and are commonly put in another part of the Journal.

The Lee-way may be entered as above, if it be necessary, but it can be of no other use, than to decide the Ship's place, more accurately than without it, by Practical Navigation; and how insufficient this is for long Voyages, experience testifies.

XVII.

Under the due practice of the several Propositions and Problems which have been here mentioned and referred

referred to, the Ship's Latitude, Longitude and other requisites will be known at the beginning of the Voyage. Every day when the Celestial Bodies appear at Sea, Observations may be applied for determining the Latitude and Longitude, and when the Celestial Bodies do not appear, the like may be found by the Courses and Distances sailed, though the Observations in long Voyages, will give the Ship's place nearer the truth.

In Voyages and parts of Voyages near the Equinoctial-line, the Meridian-distance, which is the Sum of the Departures in Miles, will be nearly equal to the sum of all the Differences of Longitude in Minutes, therefore one may be taken for the other with but little error, and the Calculation will be lessened. The like may be used near Latitudes ten Degrees North and South with no sensible error; near Latitudes fifteen Degrees, with but small error, and near Latitudes twenty Degrees, with much less error than arises from other causes; and this may be corrected by adding a very few Minutes to the Miles of Departure; therefore, in the Oceans and Seas within these limits, the Meridian-distance may be retained in Navigation, and much Calculation in the usual manner be omitted, without being less correct than by contracted Meridional-parts.

XVII.

When the Ship has been at Sea a sufficient time to have tried the several methods for Longitude before-mentioned, it may be expected that there will be disagreement among them, and therefore it will be proper to consider which of them may be most depended on.

The Longitude by the Reckoning will have been become erroneous by innumerable causes, and therefore not to be trusted to. The most careful and laborious Calculations, in making up the Day's Works (if the Ship has been several Months at Sea, and sailed

failed under a great variety of Courses and through various Climates) will be erroneous.

The Longitude by the Time-keeper, depends wholly on the Equality with which it has kept either to mean Solar-time, or to an equal rate of gaining or losing on mean Solar-time, from the beginning of the Voyage. This rate of gaining or losing on Equal-time, must also be then known to the Observer before the Longitude can by the Time-keeper be determined. If a Ship sails from England directly to India, in four Months, and to Cape Good Hope in two Months, and the Time-keeper errs from an uniform rate of going but one Second of time in a Day, it may deceive an observer when he comes to the Cape, a quarter of a Degree of Longitude, and at India half a Degree, and so in proportion for greater Error or Deception in the Time-keeper's rate of going. What must the consequences be, when the daily Error or Deception is much greater?

The Longitude taken by the Lunar Method is affected with three kinds of errors. 1. The errors in making the Observations with the best Instruments. 2. The errors in the Lunar Tables, and their Calculations for making the three-hourly distances. 3. The Calculations for the Longitude, when the observations have been made. The first of these errors, that of taking the angular Distances of Sun and Moon, or Moon and Stars, is nearly annihilated by my late Invention of adding several nonius subdivisions for Minutes along the Sextant's Arch, and a proper method of taking the Medium. The second Error, that of the Lunar Tables now used, according to the late Mr. Charles Mason's account who made them, is small. The Ephemeris states it at most fifteen Miles.

The third Error, that in making the Calculations from the Observations, is very small; my own Improvements do remove almost all sensible error, that can arise either in using the Linear Tables, or the
Sun

Sun and Moon's Angles. In both of these Methods, the errors that might arise from a variable horizontal Refraction may be avoided. To have left the Calculation very tedious, would have rendered it next to impracticable; more conciseness would have made it more difficult, and other Methods that would have shortened the Tables, would have made them erroneous, especially for Parallax in Distance.

From these considerations, and the testimony of Observers, a single set of Lunar Observations for the Longitude, is far superior to the greatest exertions of Art, for enabling observers to carry Time by Mechanism. Therefore, the Lunar Method should be preferred at all opportunities.

XIX.

When a great part of a long Voyage is performed, and the Longitude by a Time keeper differs from that by the Lunar Method, the Time-keeper may be examined, but not correctly at Sea. The Solar-time may be taken at the Ship on one Day, and on the Day following near the same Hour. These two Solar-times, must be reduced to mean Solar-time, and their difference compared with that by the Time-keeper between the two Observations. By these it will nearly appear what the Time-keeper has gained or lost in its rate of going; but this does not discover the errors that may have happened at other parts of the Voyage. Besides, this trial depends on the Ship's Reckoning, which may have been erroneous many Days, so as to deceive the Observer more than five hundred miles in an India Voyage. Therefore this Method of trusting to the Time-keeper and its corrections at Sea, is no other than trusting to the Reckoning itself.

The Limits of errors that may happen in any Method of taking the Longitude at Sea, are the greatest errors that can be supposed to happen during a Voyage, and half of that limit is the error that may be supposed

supposed to have happened in usual cases, at the end of a long Voyage. The Limit of the Lunar Method to that of the usual Method of Sailing, is by Experience and Observations found often as one to ten; that is, the Lunar Method is ten times as exact as that by the usual Method of Sailing, and the Time-keeper when tried at Sea and readjusted by the Reckoning, partakes of as great an error. When the rate of gaining or losing on mean Solar-time has been settled on Land, that rate is to be supposed at Sea; otherwise, the Longitude by a Time-keeper, will ever be uncertain in long Voyages, and the Lunar Method preferable, with common Instruments.

XX.

When it is judged that the Ship is so near Land, or a designed Port, as the limits of errors may be; care should be taken for knowing the true Latitude and Longitude, by any of the Methods that are applicable.

For the Latitude, 1. The meridian Altitudes. 2. The double Altitudes with or without Elapsed-time. 3. The usual Method of Sailing. Any of these, especially such as can be applied near Noon, should be used and registered in the Journal, as therein directed.

For the Longitude, 1. The Lunar Method by Sun and Moon, or by Moon and Star. 2. The Time-keeper, as having been readjusted, examined or supplying the want of Observation. 3. The usual Method of Sailing, carried on from a good Lunar Observation. 4. The Charts of the Coast which the Ship is approaching, should not be depended on for their Latitudes and Longitudes, unless they have been chiefly settled from astronomical Observations; and even then the greatest caution should be used. 5. The Variation should be

be carefully taken and registered in the Journal. 6. The Ship's Clock or a Watch, kept to Solar-time or to mean Solar-time, in order that when Land appears, its Latitude and Longitude may be taken, or rather Observations made to be placed at the foot of the Journal, from which the Latitude and Longitude may be easily calculated. 7. The Courses and Distances sailed taken as correctly as possible. 8. The Soundings, if any; and such other precautions as are necessary, till the Ship is in sight of Land, or near the Coast.

XXI.

When the Ship comes in sight of Land, and its Coast is well known by the Charts, the Bearings and Distances are to be taken, as the Ship is either approaching toward or passing by the Coast. The Variation still should be taken and registered in the Journal, but other particulars will appear by good Charts of Coasts and Harbours.

If the Coast be not known, or there be no good Charts of the Coast and Places adjacent; they should be taken, but avoiding Dangers, and if possible, noting their places. Then should be taken, 1. The Latitude. 2. The Longitude. 3. The Variation. 4. The Soundings. 5. The Times and State of the Tides, with such other Remarks as may be of use in future Voyages.

When a Ship is to enter the British Channel, the true Latitude and Longitude should be known long beforehand. The proper Courses should be kept to. The Variation should be known and applied. The Tides in the Channel should be known, and all Care taken off the Coast, near Land, and at the Entrance of an Harbour. This belongs to Pilotage.

April 10, 1790.

S. DUNN.

The End.